FUNDAMENTAL ISSUES IN BENEFIT TRANSFER AND NATURAL RESOURCE DAMAGE ASSESSMENT

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ABSTRACT

In this paper, we address three pertinent questions for benefit transfer. Can we reliably measure benefits within the original study context? To what extent can benefit measures that are reliable within the study context be transferred to provide reliable estimates for the policy site? How can we improve benefit transfers to make them more reliable under a wider set of conditions? Researchers must establish that the benefits estimates they are transferring are defensible themselves. Researchers should also test the adequacy of benefit transfers. by quantifying their accuracy. Finally, we need to improve our methods of transferring benefit estimates, perhaps by developing a wider range of calibration variables.

Benefit transfer estimates values in a policy context using available information from studies carried out in another context (the study context). For example, we may have an estimate of the value of recreational fishing derived from a study of coho salmon fishing in Oregon and attempt to transfer this result to estimate the value of king salmon fishing in Alaska.

Participants at the AERE workshop agree that, for practical reasons, benefit transfer is a necessary component of policy analysis. In many situations the expense of carrying out an original study cannot be justified, or the funds or time simply aren't available. Yet some information is needed to support decision making.

In a sense, even site-specific studies are a form of information transfer, where data from the sample is transferred to a more general population. In many cases, the same kinds of issues arise (e.g., Loomis, 1987). For example, researchers must be careful that the sample is representative of the larger population. In cases where the sample is not representative, researchers frequently adapt results, often using socioeconomic characteristics of the sample and the population.

Therefore, the relevant concern for economists is not *whether* to do benefit transfer; instead, we suggest three pertinent questions for benefit transfer. The first is whether we can reliably measure benefits within the original study context. We certainly shouldn't consider transferring benefit estimates that are unreliable even within their own context. The second is to what extent benefit measures that are reliable within the study context can be transferred to

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provide reliable estimates within the policy context. Reliability will depend on the extent to which values vary between the study and policy site, the extent to which we can explain and correct for these differences, and the standard of accuracy for benefit estimation. The third question is how we can improve benefit transfers to make them more reliable under a wider set of conditions.

The answers to these questions will depend on the context of the benefit transfer, where different standards might be applied in different contexts. In many arenas, our institutions have set differing standards of accuracy or burdens of proof for different kinds of social decisions. For example, society has established the most rigorous burden of proof for criminal cases, requiring the evidence to prove the case “beyond a reasonable doubt.” This standard applies independent of associated penalty and holds for criminal fines, as well as loss of personal freedom through prison sentences or the death penalty.

A weaker standard has been placed on other cases, such as in civil suits, where the standard is preponderance of the evidence. Here, the judge or jury will side with the stronger case. This standard will differ to some degree for cases that include a rebuttable presumption where a result is assumed to be correct unless a preponderance of evidence to the contrary exists.

Finally, the weakest standard of proof exists for policy decisions, where the agency making the decision only needs to show that it is not being "arbitrary and capricious." An action by an agency is considered arbitrary and capricious when the agency has

> relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of a problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view or the product of agency experience. (Motor Vehicle Manufacturers Association versus State Farm Mutual Insurance Company 463 U.S. 29, 43, 103 S.Ct. 2856, 2867, 77 L.Ed.2d 443, 458 [1983])

In contrast, an agency’s judgment will generally be accepted when it can show that it “examine[d] the relevant data and articulate[d] a reasoned basis for its decision" (NRDC v. Harrington 247 U.S. App. D.C. 340, 370, 768 F.2d 1355, 1385 [1985]). Hence, in developing regulations or in policy analysis, the agency is given considerable latitude for judgment and need not demonstrate, for example, a “preponderance of the evidence” or an absence of a "reasonable doubt”

These legal doctrines may provide one basis for establishing different standards of accuracy or acceptability of benefit transfer within different contexts. An alternative standard may be provided by a form of benefit-cost analysis whereby a higher standard of accuracy might be required when the costs of making a bad decision are high. A lower standard of accuracy might be acceptable when costs are lower, such as when the information from the benefit transfer is only one of number of sources of information, or when benefit transfer is used as a screening device for the early stages of a policy analysis.

Hence, the acceptability of benefit transfer depends not only on how appropriate the estimated value but also on the institutional context. A number that may be "good enough" to be used as part of agency judgment for a screening study may be judged to be inadmissible in a criminal case or even in a civil case, such as in litigation surrounding a natural resource damage assessment (NRDA).

However, even for screening studies, we need to apply sensible standards of accuracy. We cannot allow ourselves to accept the proposition that "some number is better than no number," particularly because an unreliable number may be given undue credibility. Benefit transfer will obstruct, rather than facilitate, rational planning and will lose credibility if we apply misinformation. In some cases we are better off acknowledging that we have no reliable estimate for a particular factor, and we can then either collect information to estimate this factor or account for it in qualitative terms.

FRAMEWORK FOR EVALUATING BENEFIT TRANSFER

The basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Consider the example discussed above, where we have an estimate of the value of recreational fishing for coho salmon in Oregon, and we attempt to transfer this result to estimate the value of king salmon fishing in Alaska. The estimate of the value of coho fishing in Oregon may not accurately measure the value for king salmon fishing in Alaska for at least three reasons:

- The preferences of participants in Alaska may differ from the preferences of participants in Oregon.
- The characteristics of the king salmon fishing experience in Alaska may differ from the characteristics of the coho salmon fishing experience in Oregon.
- The *estimated* value of coho fishing in Oregon may not measure the *true* value of coho fishing in Oregon.

The first two reasons imply that the value of fishing in Oregon differs from the value of fishing in Alaska, while the third implies that the *estimated* value in Oregon is incorrect.

Figure 1 formalizes these three sources of variation. Individual variation denotes variation across people that might arise because of differences in preferences. The value of

	"Mean" Value	Individual Variation	Commodity Variation	"Other" Variation
Fixed Component	μ	μ_I	μ_C	μ_O
Random Component		ε_I	ε_C	ε_O

Figure 1. Framework for Benefit Transfer

Alaskan king salmon fishing may differ from that of Oregon coho fishing because anglers in Alaska may have different preferences than anglers in Oregon. Some of this variation may be due to fundamental differences in tastes across individuals, while other components may be due to differences in socioeconomic characteristics like income or age.

Commodity variation denotes variation across commodities that might arise because of differences in their characteristics. The value in Alaska may differ from the value in Oregon because of differences in the two experiences. For example, on average, differences may exist in catch rates, scenery, congestion, size of fish, or other characteristics.

The third source of variation is meant to capture any variation that is independent of preferences or the commodity and thus includes "bias" or "error" in measuring value. Various sources of bias and error have been recognized in the literature. For example, using an incorrect functional form can bias regression results and subsequent value estimates. Similarly this form of variation may arise when survey respondents do not correctly express their values in a contingent valuation survey or when people act in ways that do not allow us to infer their true values through revealed preference methods.

The issue of bias has been most carefully considered for contingent valuation (e.g., Mitchell and Carson, 1989). but important biases may also exist for revealed preference methods, such as the travel cost approach (e.g., Bockstael, 1984; Smith, 1989). Many studies have attempted to test reliability and validity of benefit estimation techniques within the context of a specific study (e.g., Bishop and Heberlein, 1979; Loomis, 1989). To our knowledge, Cummings, Brookshire, and Schulze (1986) are the only ones who have taken a broad look at the issue of accuracy. We are aware of two studies that look at accuracy within the context of benefit transfer (Loomis, 1992; Downing and Ozuna, 1992).

In Figure 1, each source of variation is composed of “fixed” components and random components. The fixed components are the components of variation that in some cases can potentially be estimated and corrected for, while the random components cannot be explained.

For example, the value of recreational fishing may vary systematically over individuals because of differences in age or income. By including age and income as explanatory variables in the demand function, these sources of differences in value between the study and policy contexts can be explained, predicted, and corrected. However, tastes may differ randomly and unexplainably across individuals between the study context and the policy context,

The Oregon estimate will misrepresent Alaskan values if the distribution of these random components of participants' tastes is different in Alaska than in Oregon, after correcting for identifiable differences in the populations (e.g:, age, income). In some cases we may be able to place confidence intervals on this variation. For example, our Oregon data may allow us to estimate the variance in tastes over participants. However, we cannot guarantee that our policy site will fall within the confidence intervals because sources of variance may exist between the study and policy sites that we cannot observe within the data for the study site only. Thus, to the extent that values in the study and policy contexts differ because of random differences in tastes, we may be unable to adjust our benefit estimates to reflect these differences.

A similar problem may arise if the contribution of “identifiable” factors differs across the two sites. That is, using the Oregon coho study, we may be able to estimate how age and income affect the value of fishing in Oregon. However, these characteristics may have different effects on the value of fishing in Alaska. For example, if the weather is colder during the fishing season in Alaska, age may be a more significant factor in Alaska. Similarly, two regions may have cultural differences, so that in one region participants in some age group would not be “caught dead" fishing, while this attitude may not be a factor in the other region. Again information obtained in one region may not be transferable to another region. Furthermore, if no studies are available in the policy region, we may have no systematic means of identifying or measuring these sources of variance.

The three sources of variation may be viewed somewhat differently in terms of three components of benefit transfer. The first component consists of the "knowns," or the differences between the study context and policy context for which information is available and that can be estimated. For example, we may be able to estimate how the value of fishing varies with income, age, and catch rates. Using the known (or knowable) information, such as demographic information and characteristics of the activity, we can adjust the estimates of value obtained for the study context to produce estimates for the policy context.

The second component consists of the "known-unknowns," which might include the random components of the individual or commodity variation. For example, preferences may differ in ways that we cannot explain, but we may nevertheless be able to estimate the variance due to these effects at the study site. Thus these random components may be accounted for by using confidence intervals on the estimates. Alternatively, known-unknowns might also arise because of variables that are known to affect value but for which no data are available at the policy site. We may know how income affects value, but we may not have data on income of participants at the policy site. One way of accounting for these effects would be to use sensitivity analysis to place plausible upper and/or lower bounds on these variables.

Finally, "unknown-unknowns" could arise in the original study from the "other" sources of variation discussed above, or from unobservable or unknown differences between the two populations and/or commodities. Limiting the magnitude of the unknown-unknowns is crucial to the success of the benefit transfer. However, the magnitude of these sources of variance is, by definition, not known to the researcher, and the researcher generally has no way to quantitatively account for them in the transfer, short of carrying out a study at the policy site.

In the case of unknown differences between the study context and policy context, one possible approach is to use a pilot study to assure that results appear to be transferable. Of course, the cost of carrying out such a study may negate much of the cost savings that may come from benefit transfer.

Thus, the answers to the first two questions posed earlier-whether we can reliably measure benefits in the original study context and whether we can reliably transfer benefit estimates-depend on the types of variation that occur and their magnitudes and on how well we can identify and measure them. For benefit measures to be suitable for transfer, unexplained variation must be limited to an "acceptable" level. The margin of error that is "acceptable" will depend on the appropriate reliability standard, as described above.

TESTING AND IMPROVING BENEFIT TRANSFERS

We might judge our confidence in the soundness of a benefit transfer in several ways. Generally, statistical tests are used to evaluate the original study. These tests include statistical significance of explanatory variables, the equation R^2, and the size of prediction intervals. The significance of important explanatory variables, such as the travel cost coefficient, is necessary but not sufficient proof of the validity of value estimates. In addition, the model must have acceptable explanatory power, which is indicated by the R^2 and prediction intervals. Typically, economists focus on statistical significance and tend to ignore R^2 and prediction intervals.

These statistics suggest the relative magnitudes of the knowns and the known-unknowns, but they will not measure the effects of the unknown-unknowns. Therefore, we can only really be certain about negative test results. If a model has poor explanatory power for the study site, we will not have much confidence in its soundness for benefit transfer. However, a model may have good explanatory power, but extrapolation of its results outside of the original sample may imply that we cannot measure important components of the variance-the unknown-unknowns-so that the model may not provide good benefit estimates for the policy site.

Given the above problems, researchers should place greater emphasis on testing and calibrating benefit transfers. Socioeconomic variables, which are typically used as calibrating variables in transfers, often have very low explanatory power, implying that they are not good calibrating variables for benefit transfer. Consequently, we need to be more creative in the variables used for transfer and focus research efforts on finding variables that better explain variations in preferences.

For example, attitude statements about the importance of an activity or the experience level of participants might be one type of variable that would improve the explanatory power of models and transfers. Travel cost and contingent valuation surveys could include a series of attitude statements, answered on a scale of one to ten, about the importance of an activity or the respondent's experience level. If these variables have good explanatory power they could be used to calibrate the transfer.

One reason that socioeconomic variables are generally used to calibrate transfers, despite their low explanatory power, is that these are the variables for which data are easily available. To use other calibrating variables researchers might conduct a small "calibration" survey for the policy site, where respondents are only asked to answer the same series of attitude/experience questions asked in the original study. The results from the original study could then be weighted by the attitude/experience values for the policy site to calibrate the transfer. Again, we should be

Anchorage oil spill cost nearly $250,000 to conduct, but natural resource damages were estimated at $32,000 (Washington State Department of Ecology, 1987).

In recognition of these issues, researchers have developed a variety of structures for benefit transfer. For example, the Department of Interior (DOI) has developed the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), which is a structure for benefit transfer based on a computer model that simulates the physical fates of a spilled substance, the biological effects of this spill, and the resultant economic damages (e.g., Grigalunas, Opaluch, French and Reed, 1989; Jones, 1992). Alaska and Washington State have developed more *ad hoc* approaches for simplified damage assessment that use damage indexes based on the properties of the substance spilled and the environment in which the spill occurs. In formulating the regulations for the Oil Pollution Act (OPA), the National Oceanic and Atmospheric Administration (NOAA) is considering using compensation tables, the NRDAM/CME model, and other means of “expedited” damage assessment. Many damage assessments have been based on more “traditional” applications of benefit transfer, where available estimates of impacts, such as body counts or lost beach days, are combined with available estimates of the values of the resources to estimate damages (e.g., Washington State Department of Ecology, 1987).

Most of the NRDA work by economists attempts to calculate the value of lost services due to a spill. This approach is based on the usual definition of Hicksian compensation:

$$C = E(P, NR^0, U^0) - E(P, NR^1, U^0) \tag{1}$$

where C is monetary compensation required to make the individual whole, $E(\bullet)$ is the expenditure function, P is a vector of market prices, NR^0 is the without-spill vector of natural resources, NR^1 is the with-spill vector of resources, and U^0 is the without-spill level of utility. Thus, monetary compensation is the difference between the with-spill and without-spill levels of expenditure needed to achieve the fixed level of utility. The aggregate level of compensation required can be calculated by aggregating over all individuals. This level is often calculated by estimating compensation required by a "representative" individual and then multiplying by the size of the affected population.

However, under CERCLA and OPA, a strong preference is expressed for making the public whole by restoring injured natural resources rather than providing monetary compensation (e.g., Mazzotta, Opaluch, and Grigalunas, 1992). Additionally, all funds collected, including

The cost-effective restoration program that makes the public whole is defined by

$$\min_{R} \; C(R)$$

s.t.

$$\begin{aligned} U(P, Y, NR^0) &= U(P, Y, NR^1 + R) \\ C(R) &< F_{GP} \cdot [E(P, NR^0, U^0) - E(P, NR^1, U^0)] \end{aligned} \qquad (3)$$

where C(R) is the cost associated with restoration program R, E is the expenditure function, and F_{GP} is a factor of gross proportions, as described below. The first constraint requires that the public be made whole through resource restoration, R, and the second constraint requires that the cost of restoration not be “grossly disproportionate” to the value of the resource. This sort of constraint is implicit in the Ohio Decision, where the court suggests “the rule might for instance hinge on the relationship between restoration cost and use value (e.g., damages are limited to three-times the amount of use value)” (U.S. Court of Appeals, 1989, footnote 7. p.21). Thus, the Court’s suggestion for grossly disproportionate would be based on a factor of gross proportions (F_{GP}) of 3.

Equation system (3) is equivalent to the traditional expenditure minimization problem of utility theory with two exceptions. First, OPA and CERCLA’s restriction that the funds must be used to “replace, restore, rehabilitate or acquire the equivalent" implies that the resulting expenditure function is restricted in the commodities that can be purchased. This restriction is reflected in the fact that the minimization is over R, not over all possible commodities. Second, the purchases are constrained to those sets that are not “grossly disproportionate” to the value of the resource.

In practical terms, the solution to this problem would progress in stages. For example, researchers could fast identify a number of feasible restoration plans and estimate the time path of recovery for various resources under each plan.

Next, researchers could identify “equivalent” resources to restore, in terms of social preferences. Here, researchers could use standard discrete choice models, where a sample of respondents are presented with alternative programs for restoration, described in terms of the resources and time frame for each. The respondents would then be asked to choose the most preferred restoration programs or to rank alternative programs. Standard methods of discrete choice analysis (McFadden, 1973) could then be applied to determine the levels of restoration for

> compensate fully for the injury. Congress refusal to view use value and restoration cost as having equal presumptive legitimacy merely recognizes that natural resources have value that is not readily measured by traditional means. (U.S. Court of Appeals, 1989, p. 51)

This quote suggests that Congress' intention was not to suggest that full restoration always be carried out. “regardless of cost and regardless of whether anybody cares,” but to make sure that the value of resources are not systematically understated.

Although the intentions of Congress are not stated clearly, an alternative to Hanemann’s (1992) interpretation would allow for an anthropocentric approach such as that presented above, where the objective is to *make the public whole* in terms of maintaining the value *to the public* of the stock of resources and associated services, rather than to *make the environment whole* regardless of public values. This interpretation is also consistent with the idea of gross proportions.

Duffield also addresses this issue, discussing the fact that requiring full restoration of injured resources is based on an equity goal and is likely to result in losses in economic efficiency (Ward and Duffield, 1992). He states that Congress expressed a preference for *full* restoration, which will often be economically inefficient. Yet, the DOI proposed regulations under CERCLA do not require that damages be calculated as the cost of full restoration but that some combination of restoration and compensation be chosen. A “reasonable number” of alternatives must be considered, and these alternatives must include the possibility of "no action-natural recovery." Although restoration is still the preferred goal, combining *both* economic efficiency and the idea of restoration is possible under the proposed regulations.

Hanemann (1992) and others see restoration as based on the deontological principle so that “economic analysis plays only a minor role, associated with calculating restoration costs and cost-effectiveness. It is under the anthropocentric approach that economics moves to center stage” (p. 574). However, the notion of restoration as in-kind compensation is useful for framing the restoration problem as one of compensating the public in a cost-effective manner, while remaining compatible with the expressed Congressional preference for restoring damaged resources. If we view restoration from this anthropocentric viewpoint, economists play a critical role.

SUMMARY AND CONCLUSIONS

Benefit transfer is a necessary and important economic tool for practical policy analysis. However, to establish and improve the credibility of benefit transfer we need to place greater

BENEFITING BENEFITS TRANSFER: INFORMATION SYSTEMS FOR COMPLEX SCIENTIFIC DATA

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ABSTRACT

In this paper, I suggest reorganizing the science on which we build benefits estimates. I advocate developing a system for sharing data, creating support for archiving scientific measurements, and making data easier to use.

This paper advocates reorganizing the science on which we build estimates of benefits. Reorganization implies four imperatives:

1. Build an effective system for sharing data, an Information System for Complex Data (ISCD).

2. Create necessary support for archiving scientific measurements.

3. Begin now. Deploy existing computer and software capabilities to reduce learning time for secondary use of data, to increase scope of questions that can be addressed to existing data, and to anticipate the arrival of new generations of software and hardware.

4. Change incentives.

WHY BUILD ISCD?

Positive Reasons

Benefits transfer is applied science, statistical science, implying the following:

- Estimates of benefit are simulations based on empirical fact Observations and models of those observations are used to simulate out-of-sample forecasts for benefits transfer.

- The procedure for benefits transfer must be reproducible. Reproductibility keeps the estimates out of court and away from accusations of fraud.

- Bounds on error in estimates are needed to tell us how good the estimate is. We have more certainty about the value of the salmon fishery, governed by market prices, than we have about the value of wilderness, whose nonmarket externalities preserve options, species, and perhaps even climate.

- Learning-by-doing. Over time we expect the error of benefit estimates to decline. The scope of estimates will increase as the range and quality of measurements increases.

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benefit estimation and will likely lose credibility as a policy tool. This potential effect suggests that we should focus our attempts at benefit transfer on obtaining a smaller number of studies that fit the policy context most closely, rather than obtaining the largest number of studies possible, where many may not fit the policy context.

Other interesting issues regarding benefit transfer arise within the context of NRDA. Because the statutes express a strong preference for restoration of resources over monetary compensation, we need to develop methods to evaluate restoration alternatives. More specifically, we need to identify restoration programs that will make the public whole in the least costly manner and whose costs are not grossly disproportionate to the value of the injured resources. We also need to determine the extent to which these measures of compensation are transferable across contexts.

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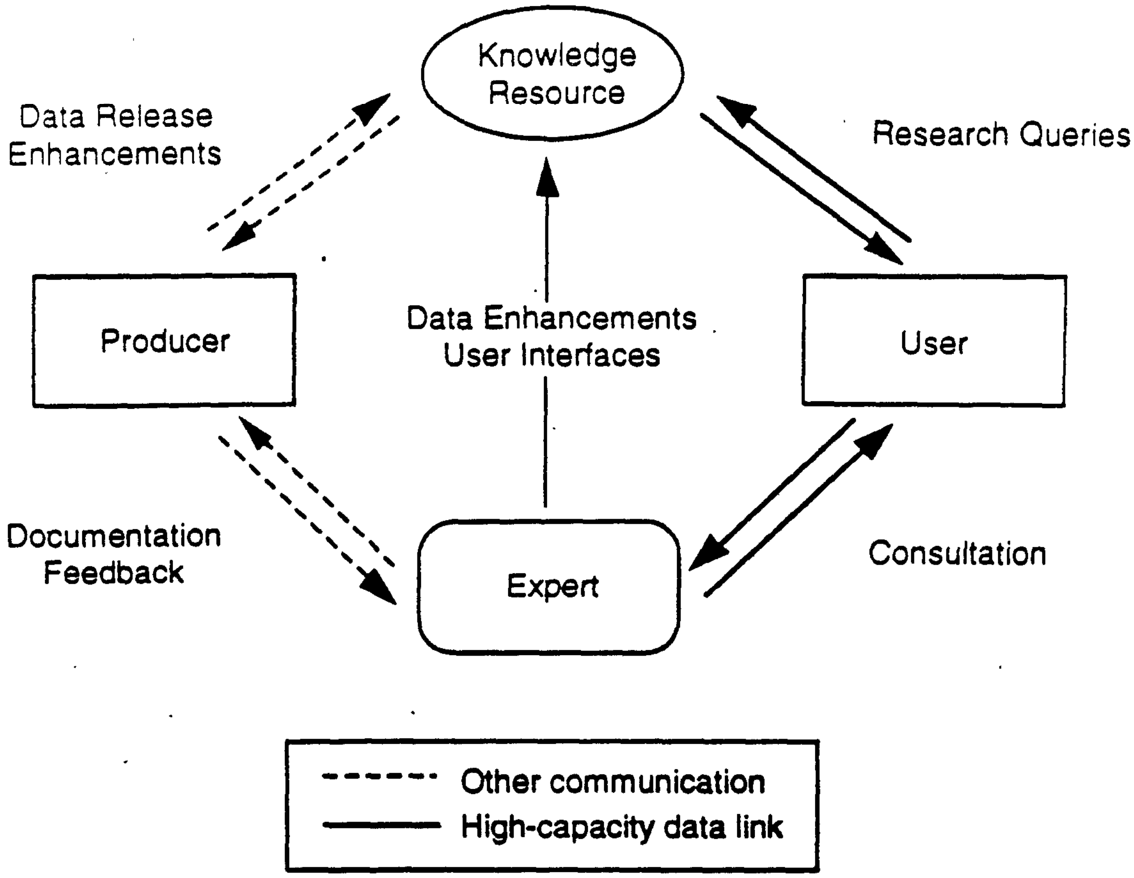

Figure 1. An Information System for Complex Data

scientists call a domain specialist, a diagnostician who can solve problems in interpreting data in one-on-one consultation or who can alter the computational capability to teach many users to solve the problem for themselves. (This keeps cost down.)

The knowledge resource integrates software and data in a system that can respond to inquiries from users. Pre-programmed artificial intelligence and carefully designed data structure (the database schema) speed the recovery of frequently used data and description. The knowledge resource includes several critical elements: a body of data accessible for statistical analysis (e.g., a SAS system file), descriptions of the data that provide necessary support, an archive of reports generated from the data, and bibliographic databases that can be searched for citations, data sources, and subject arc crucial to the process of learning about and using data. At Wisconsin many of these capabilities were organized in a relational database management system (RDBMS). The power of those systems is explained in the Appendix.

- Conceptual level-When are the numbers real? When are numbers imputed? When are numbers randomly altered, “fuzzed” (to limit disclosure)?

- Consequences of using each datum: What unusual interpretations? When are zeroes null? When are values truncated?

- Inference from the data: How can honest inferences be made from the data? Does selection bias inference from reports? Does variance in the measurement process mask real world phenomena? Is the measurement process biased by moral hazard?

All of this information can be embedded in and linked to the RDBMS that contains the measurements. Table 1 contains a summary of the kinds of information that should be stored in an ISCD to provide necessary support for the secondary data researcher.

WHAT PAYOFFS DO ISCD NECESSARY SUPPORT CREATE FOR BENEFITS TRANSFER?

Three kinds of payoff follow from organizing data on economic benefits in an ISCD: discovering the state of the art of benefit measurement will be less costly, synthesizing benefit measurements will be easier, and incorporating superior methodology in estimating models on larger sets of data will be possible.

State-of-the-Art

Garner’s bibliographic database (circulated for the AERE conference) represents an important step towards an ISCD for benefit measurements. Citations to reports about what we already have discovered are accessible. The perspective of the ISCD, says Garner, should add one element to the bibliographic database-a title for each dataset exploited in each report Titling and citing datasets are the only ways to establish the empirical foundation for any analysis. The title concept is implemented in Roistacher et al. (1980) but has not found its way into accepted referencing for scientific publication or into bibliographic databases. The perspective of an ISCD implies that the database is complemented by electronically stored files containing each of the reports and articles cited. Electronic preservation of reports allows any user to review any document cited. Archiving scientific work in this way assures permanence for the published record.

Because many excellent datasets are collected to pursue contractual obligations, reports containing important datasets are difficult to find-even in the contractor’s archives. This makes electronic archiving of reports critical.

Synthesizing Measurements

Smith and Huang (1991) undertook to synthesize measures of willingness to pay for air quality from data on the housing market in areas with differing levels of air quality. Their analysis searched over fifty statistical studies spanning two decades of observations. The response that Smith and Huang seek to estimate is the marginal rate of substitution between price paid for housing and particulate deposition. Underlying that measure of response is a model of the price paid by individuals for residential housing units in various urban areas of the U.S.

Smith and Huang develop an excellent "meta-analysis" *of models fit to the underlying data.* Their work synthesizes past investigation but cannot recover much of the variability in underlying data (because each model is a projection of the underlying data into a small number of dimensions). Furthermore, the technique fails to recover any direct information about the dynamics of willingness to pay; all human response to pollution is inferred from differences in prices paid by similar people buying housing in different places.

Crippling Problems

This study faced extreme difficulties and I admire the authors for their perseverance:

- Assembly. The study required assembling 26 journal articles, 5 unpublished papers, 5 dissertations, and 1 edited volume.
- Incomplete estimates of response to air quality. Many studies did not contain responses to ozone, SO_2, and other indicators of air pollution The meta-analysis is confined to understanding response to particulates (arguably the most obvious aspect of air quality). Models that did not include particulates had to be excluded.
- Reuse of data. The same data were used to estimate several models, both within and between research teams. For that reason models estimated are not independent.
- Incomplete documentation. Some papers failed to describe either the data or estimating method in sufficient detail to permit meta-analysis. Contact with one researcher filled some lacunae. In other cases pollution data were augmented; still other models could not be included in the meta-analysis.

Limitations of the Approach

Some of the studies are based on measures of house value and air pollution that are aggregated over space (e.g., Census tracts). A second problem is that the studies use a variety of measures of willingness to pay: samples of sales data, samples of FHA-mortgaged properties, samples derived from the Census self-reported house values, and the Annual Housing survey.

"documented " and "titled" Funding institutions can also require the deposit of completed publications in a data-oriented library. Funding institutions are in a position to provide necessary, resources and to enforce their agreements with data collectors.

Funding institutions cannot proceed without support from the professions. Journals need to require citation of data sources. They also need to require datasharing that permits replication of published findings. Some journals have already adopted this point of view *(AER, JHR, and JEEM).*

These changes in institutions and journals are easy. Change in our own professional conduct is also needed. While the computational capability to create low-cost datasharing is available on most desktops, social conventions need to be forged to support effective datasharing. Just as we have conventions to drive on the right and stop at the red signal, we need conventions on a common system for organizing shared data. Up to now, we have been unable to specify completely what is required for data-sharing. Concepts from computer science clarify what is needed at the same time that those concepts forged the technology that we can now use to organize data.

Experience at Wisconsin shows the efficacy of ISCD. Computer science has given us the relational data model, which organizes data and necessary support for data in a common framework. The geniuses of Silicon valley have given us technology that makes the computational costs of ISCD trivial in comparison to the cost of professional time. So long as we do not implement ISCD, much professional time will be wasted in searching for the right data, the right model, and implementing the simulation required for benefits transfer. Do we really want to waste scarce resources for learning about the environment?

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APPENDIX A

RELATIONAL DATABASE MANAGEMENT SYSTEMS-RDBMS

In the past dozen years computer scientists have discovered important principles for storing and retrieving large volumes of numerical data and smaller volumes of text. Their ideas culminated in relational database management systems (RDBMS) technology that is now available to every PC owner for about the same price as a spreadsheet program.

RDBMS denotes a system with several essential features, starred in Table A-1. The systems were designed to meet needs for commercial “transactions processing," whose requirements are somewhat different from scientific statistical processing, although the commonalities are much greater than most social scientists understand. The systems are designed for multiple users-both multiple data suppliers (i.e., points of data entry) and multiple researchers. RDBMS are designed to support interactive use of the data at all times and maintain an unambiguous outcome for statistics (reports in the RDBMS jargon) that are generated at any point in time. This feature is called data concurrency.

A mandatory requirement for RDBMS is dynamic independence. Adding new data to the system without restructuring the existing data must always be possible. For example, successive measures of pollution control and abatement expenditures (PACE) can be loaded into the system without knowing about or interfering with older data. Contextual data can be added to the system without determining the attributes used to link those data to individuals in advance. Thus interview data obtained from households can be loaded without knowing that their report of industry affiliation might subsequently be used to assign worker exposure to safety risks or that geography might later be used to assign prevalence of radon exposures.

Data entry is controlled by logical rules that can draw on any part of the existing data to enforce consistency; consistency may be applied to individuals, households, firms, activities (other entities), and combinations of entities. Consistency rules are called integrity constraints on the database. Referential integrity implies that adjustments to the database do not leave garbage in the system. For example, if an individual is found to be associated with the wrong address, all traces of that individual are dissociated from that address when the address is corrected.

For researchers the most important property of RDBMS is its “query language.” Requests for information are written in the query language, which has a simple structure derived from concepts of mathematical logic. Query languages support *any* logical operation on *any* mathematical or lexical function of the attributes or variables in the database. Query languages are compact, and SQL has been adopted as an industry standard that will be supported by all database vendors.[1]

RDBMS provide permanent housekeeping that is essential when multiple points of entry and multiple users must be accommodated. Finally, the RDBMS support sophisticated security and reporting. Users can be restricted, from access to particularly sensitive data. Operations can be monitored continuously by reports on the capture of interviews, error-rates, outliers, and interviewer comments.

The logic of RDBMS results in “flat files,” rectangular arrays that are easy to move outside of the RDBMS environment. Furthermore, the RDBMS encompass two capacities that aid a complex data collection through a nation-wide system. The databases support “distributed databases" whose parts may reside on different computers. For example, the database required for sampling can be separated from the data generated by interviewing. The second capability is “platform independence” that assures the system operates in the same manner on all hardware using identical programs or applications.

The most important feature of RDBMS for a complex data collection is that it maintains a vocabulary of names for each measurement, each transformation, and each relationship encompassed in the database, no matter how many users are proceeding to make independent uses of the data.[2]

Table A-1 lists aspects of RDBMS that are critical for successful processing of scientific data pertaining to the environment

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1 RDBMS apply artificial intelligence to minimizing the cost of executing the query. Therefore, execution of particular requests does not proceed in the procedurally defined manner of scientific programming languages and statistical processors. This feature implies that embedding scientific programming languages in the database (and all RDBMS support such capabilities) causes poor performance. Understanding the strengths of the RDBMS, however, allows us to design interfaces to statistical processors (e.g., SAS and SPSS) that permit the RDBMS to locate required data efficiently while permitting the aggregation of data across entities to proceed equally efficiently. The merit of such interfaces is that inefficiencies of data management and storage in statistical processors can be eliminated without eliminating the finely tuned calculation of estimates that those processors support.

2 This capability makes it possible to generate new databases from the existing metadata that describe the survey instrument and automate the evolution of the database as each panel proceeds and as new panels are created. The result is greater productivity in manipulating on-going change to the structure of the database and greater clarity in the documentation and diagnostics produced for the documentation of data-processing steps.

APPENDIX A

ECONOMIC ANALYSIS AND RESOURCE BRANCH ENVIRONMENTAL BENEFITS DATABASE

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APPENDIX B

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